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An estimation of traffic related carbon monoxide emission in the city of Nis

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Abstract

Road traffic represents one of the largest sources of pollution in urban areas. Besides carbon dioxide and water vapor other combustion products are emitted as a consequence of fuel combustion in engines, such as carbon monoxide, hydrocarbons, nitrogen oxides, char etc. In this paper, the assessment of carbon monoxide emissions from road traffic in the city of Niš was carried out. On the basis of the road traffic fleet composition and measurements conducted during technical inspection of vehicles, an assessment of carbon monoxide emission was done and possibilities for its reduction were analyzed.

Keywords: air pollution, carbon monoxide, emission, road traffic, hazard.

Introduction

Impact of pollutants, as a consequence of a road traffic activity (CO, NO_x, SO_2, SO_x, VOC) has been very well documented (Nejadkoorki, et al., 2008), (Machadol, 2004). Due to the growing need for mobility, the road traffic is becoming a growing source of the pollution. Countries with rapid urbanization, such as India and China (Nesamani, 2010), (Du, Geng & Sun, 2009) are becoming increasingly dependent on automobile transport, which is becoming a major air pollutant in urban areas (Nesamani, 2010), (Sturm, et al., 1997), (Zivkovic, et al., 2010). Similarly, in the city of Niš, carbon dioxide emissions from road traffic represents as much as 38% of the total anthropogenic emissions (Zivkovic, et al., 2010). Although the measurement of gas concentrations itself is not difficult, a closer determination of traffic sources is very complicated considering its stochastic nature (Du, Geng & Sun, 2009). For this reason, the different methods for modeling emissions from traffic are emerging. Such estimates are of great importance for more efficient management of air quality. An emission from traffic depends on many parameters: vehicle type, engine displacement, age, fuel and its usage. Such data, when they are sufficiently determined, could be used for building a national inventory of emissions (Machadol, 2004), (Baldasano, 1998), (National Atmospheric Emissions Inventory, 2003). In recent years there have been significant efforts in determining emissions in the function of engine types, engine displacement and the cruising speed (Andre & Hammarstrom, 2000), (Washburn, Seet &Mannering, 2001), (Nesamania, et al., 2007). Based on these studies, various models for prediction of gaseous emissions were developed (Nejadkoorki, et al., 2008), (Machadol, 2004), (Haan & Keller, 2000), (Kassomenos, Karakitsios & Papaloukas, 2006).

An estimation of road traffic emission in the City of Niš was done on the basis of vehicle specific emission data, number of vehicles in the city and used fuel. Further measurements for their reduction were proposed.

Road traffic fleet in the city of Niš

According to data obtained by IT Sector - MUP Niš in the year 2010 vehicle fleet consisted of 60720 personal vehicles. According to the type of fuel used by cars, the largest number of cars runs on gasoline - approximately 63% (Figure 1). Figures 2 and 3 shows data on the composition of the fleet at the age of the vehicle or the engine capacity. Based on these data, it could be concluded that the average vehicle in the city of Niš is about 14 years old and has a engine displacement of 1.4 litters.

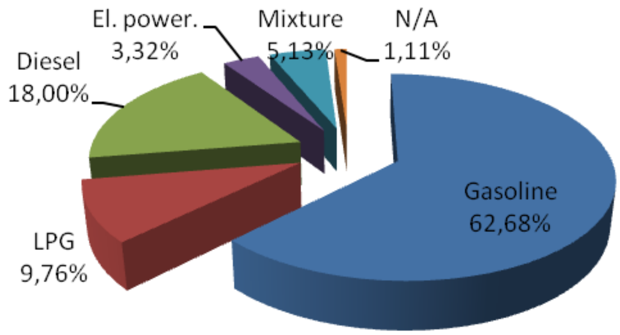

Figure 1. Vehicle fleet composition in respect to fuel

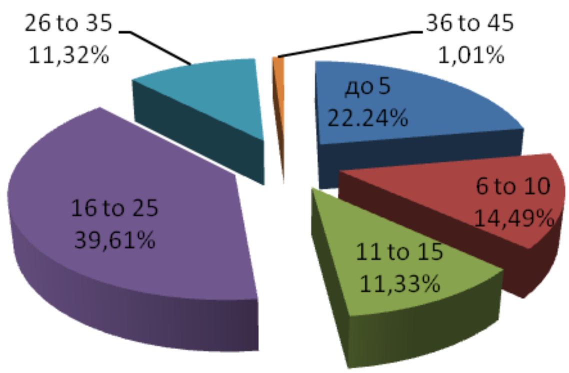

Figure 2. Vehicle fleet composition in respect to age

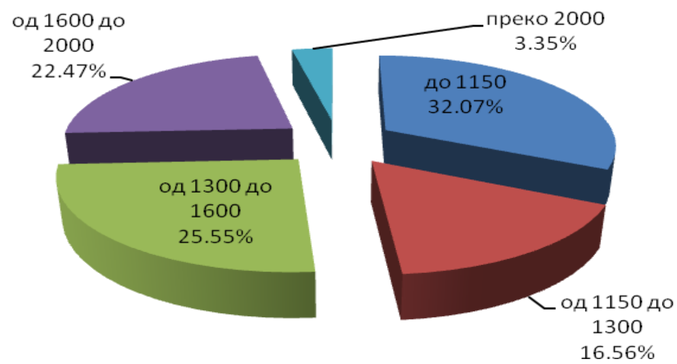

Figure 3. Vehicle fleet composition in respect to engine displacement

Carbon monoxide emission from personal vehicles with gasoline engines

For a theoretical consideration of carbon monoxide emissions from gasoline combustion, isooctane combustion model was used. For the combustion analysis GASEQ software package was used (Gaseq 2014). The simulation results are shown in tab. 1.

Table 1. Emissions from isooctane combustion

Component	Volume composition *r* [%]	Mass composition *g* [%]
N_2	72,1	71,58
H_2O	13,2	8,43
CO_2	10,35	16,1
CO	1,97	1,96
O_2	0,68	0,77
NO_x	0,7	0,74
Rest	1<	1<

As it was expected results of simulation have shown nitrogen, carbon dioxide and water vapor makes more than 95% of volume and mass composition. Next component in the table is the carbon monoxide with 1.97 volume percent, or 1.96 weight percent. In the tab. 2 the results of carbon monoxide volume share measurements are presented. Measurements of exhaust gases at technical inspection are presented in the tab. 2. As shown in the table the average emissions of carbon monoxide values 1.4 volume percents, which approximately corresponds to its the mass fraction (tab. 1). Considering the fact that the weight percentages of carbon monoxide and carbon dioxide are mutually dependent, and that the emission factor is directly proportional to mass fraction, the following proportions could be written:

$$\frac{E_{CO2,gas}}{g_{CO2,gas}} = \frac{E_{CO,gas}}{g_{CO,gas}}, \quad (1)$$

where $E_{CO2,gas}$ and $E_{CO,gas}$ represents emission factors of carbon dioxide and carbon monoxide per kilometer for gasoline engines and $g_{CO2,gas}$ and $g_{CO,gas}$ represents mass fraction of carbon dioxide and carbon monoxide. Based on the research presented in the paper (Milutinović & Tomić, 2012). the value of carbon dioxide emissions factor for vehicles with gasoline engines is 241 gkm^{-1}. Hence, the emission factor for carbon monoxide emission for gasoline engines is

$$E_{CO,gas} = \frac{242}{0.17} 0.014 = 19.93 \text{ gkm}^{-1}. \quad (2)$$

The high value of the emission factor could be explained with old engine technology, as well as with age of the vehicle fleet.

Table 2. A review of carbon monoxide emission for vehicles sampled at technical inspection

Vehicle type	**Fuel type**	**Vehicle age [years]**	**Engine power [kW]**	**Engine displacemet [cm^3]**	**Carb. mon. em. [%]**
Peugeot 206	Unlead gasoline	12	55	1360	0.8
Renault Clio 1.4	Unlead gasoline	13	55	1390	1.4
Fiat Punto 1.2	Unlead gasoline	12	44	1242	1.7
Peugeot 106 1,1 sport	Unlead gasoline	13	44	1124	1.4
Fiat Brava sx	Unlead gasoline	16	59	1370	1.4
Vw Golf 1.6 16v basis	Unlead gasoline	12	77	1598	1.4
Average	-	14	56	1347	1.35

Carbon monoxide emission from personal vehicles with diesel engines

In a study which was conducted by the Croatian Center for Vehicles (2004), the values of carbon monoxide, NO_x, hydro-carbonates and char emissions were studied and their relative ratios were established for gasoline and diesel engines. It was found that the emission of carbon monoxide from diesel engines is 2.75 times lower than emissions from gasoline engines (fig. 4). According to that, from the value obtained in eq. (2) carbon monoxide emission factor for diesel engines is equal to:

$$E_{CO,diesel} = \frac{E_{CO,gas}}{2,75} = 7.25\ \text{gkm}^{-1} \quad (3)$$

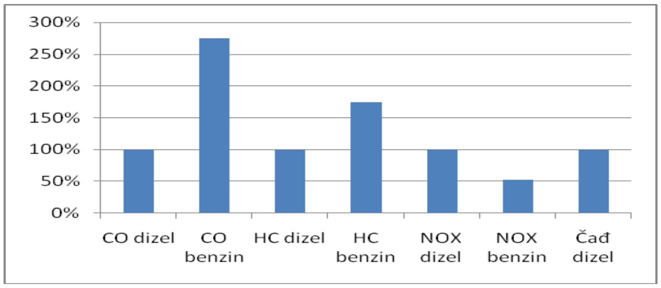

Figure 4. Comparison of exhaust emissions from diesel and gasoline engines (Croatian Center for Vehicles, 2004)

Carbon monoxide emission from personal vehicles with lpg engines

Liquefied petroleum gas - LPG is a very suitable fuel, viewed from the ecological point of view. In the combustion LPG easily forms a mixture with air and burns well, wherein the products of incomplete combustion (carbon monoxide, carbon black, carbon monoxide *etc.*) are formed in very small amounts. In comparison to gasoline, emissions of carbon monoxide are up to 1.8 times lower (Health & Environment, 2014) and it is closer to the emissions from combustion of diesel fuel. Therefore the emission factor of carbon monoxide for LPG engines is

$$E_{CO,lpg} = \frac{E_{CO,gas}}{1,8} = 11.07\ \text{gkm}^{-1} \quad (4)$$

Possibilities for reduction the total emission of carbon monoxide

For the study of possibilities for carbon monoxide emissions reduction from the road traffic, four scenarios were analyzed:

1. Scenario 1 - busyness-as-usual;
2. Scenario 2 - LPG driven gasoline engines;
3. Scenario 3 - partly renewed fleet;
4. Scenario 4 - totally renewed fleet.

Based on data fleet composition data (fig. 1-3) and obtained emission factors (eq. 2- 4), a mean value of the carbon monoxide an average emission factor for could be calculated, and for the first scenario it is equal to:

$$E_{CO,SC\ 1} = 15.98\ \text{gkm}^{-1} \tag{5}$$

If it is assumed that the vehicles in the city are driven 10 km per day, an annual emissions could be estimated for the entire fleet - 3387 tyr^{-1}.

The total carbon monoxide emission could be reduced, if the LPG was used instead of gasoline, thus by averaging the emission factor for the second scenario the average emission factor is

$$E_{CO,SC\ 2} = 10.32\ \text{gkm}^{-1}, \tag{6}$$

and therefore the annual emission of carbon monoxide 2187 tyr^{-1}.

Further, if it is assumed that one third of vehicle were substituted by newer vehicles up to 5 years old (scenario 3), which are by EURO V standards with carbon monoxide emission of 0.5 g (European emission standards, 2014), then the mean value of emission factor is equal to

$$E_{CO,gas,SC\ 3} = 0.7E_{CO,SC\ 1} + 0{,}3E_{CO,EUROV} = 11.33\ \text{gkm}^{-1}, \tag{7}$$

and overall annual emission 2403 tyr^{-1}.

In the last scenario it was assumed that vehicle fleet was completely according to EURO V standards (Health & Environment, 2014) and thus the total annual emissions would be less than 106 tyr^{-1}, so it is clear that the largest emission reductions could be achieved by the fourth scenario. In this scenario the total emissions of carbon monoxide is only the 3% from the current value presented by the first scenario (tab. 3). However, considering the current economic situation this scenario is very unlikely. The following most favorable scenario is the second one. In the second scenario the annual emission in comparison to the first scenario is reduced for 1200 tyr^{-1}. Almost the same result could be obtained in the third scenario, thus if the ratio of prices LPG and gasoline were taken into account the second scenario is the most realistic for reducing of carbon monoxide emission.

Tab 3 Emissions factors of carbon monoxide and total annual emissions for different scenarios

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Emission factor [gkm^{-1}]	15,98	10,32	10,8	0,5
Overall emission [tyr^{-1}]	3387	2187	2403	106

Conclusion

In this paper methodology for determining carbon monoxide emission from the road traffic in the city of Niš are presented. On the basis of measurements and simulations the emission factors for the different vehicle types and for the entire vehicle fleet were calculated. The results showed that given the current composition of the fleet, there are significant opportunities to reduce emissions and improve air quality.

References

Andre, M., Hammarstrom, U., (2000). Driving speeds in Europe for pollutant emissions estimation. *Transportation Research Part D*, 5 (2000), 321-335.

Baldasano, J. M., (1998). Guidelines and formulation of an upgrade source emission model for atmospheric pollutants. *Air Pollution Emissions Inventory, ed. J. Baldasano and H. Power, Vol. 3, Computational Mechanics Publications*, Southampton, UK.

Croatian Center for Vehicles, (2004). Testing of the motor vehicles exhaust gases - eco test (in Croatian), Drugo izmijenjeno izdanje, 107 (2004), Zagreb, 32

Du, Y., Geng, Y., Sun, L., (2009). Simulation model based on Monte Carlo method for traffic assignment in local area road network, *Front. Archit. Civ. Eng. China, 3* (2009), 195–203.

European emission standards, (2014). Available at http://en.wikipedia.org/wiki/European_emission_standards

Gaseq, (2014). Available at http://www.gaseq.co.uk/

Haan, P.D., Keller, M., (2000). An Emission factors for passenger cars: application of instantaneous emission modelling, *Atmospheric Environment 34*,. 4629-4638.

Health & Environment, (2014). Available at http://www.apafuel.com.au/main_pages/health_&_envir.html

Kassomenos, P., Karakitsios, S., Papaloukas, C., (2006). Estimation of daily traffic emissions in a South-European urban agglomeration during a workday. Evaluation of several "what if " scenarios. *Science of Total Enviroment, 370*, 480–490.

Machadol A., (2004). Air emissions inventory of the public transport in maracaibo municipality. Part I: Passenger car. *Revista Técnica de la Facultad de Ingeniería Universidad del Zulia*, 27 (2004), 202-209.

Milutinović, B., Tomić, M., (2012). Specific emission factor determination for vehicles fleet in the city of Niš, *Zbornik radova VTŠ-Niš*, 35 – 38.

National Atmospheric Emissions Inventory, (2003). Vehicle speed emission factor database for all pollutants (version 02/3). UK: National Atmospheric Emissions Inventory.

Nejadkoorki, F., Nicholson, K., Lake, I., Davies, T. (2008). An approach for modeling CO_2 emission from road traffic in urban areas. *Science of the total environment*, 406 (2008), 269-278.

Nesamani, K.S., Chu, L., McNally , M.G., Jayakrishnan, R., (2007). Estimation of vehicular emissions by capturing traffic variations, *Atmospheric Environment, 41*, 2996–3008.

Nesamani, K., S., (2010). Estimation of automobile emissions and control strategies in India, *Science of the Total Environment*, 408 (2010), 1800 – 1811.

Sturm, P., Almbauer, R., Sudy, C., Pucher K., (1997). Application of computational methods for the determination of traffic emissions, *Air Waste Manage Assoc*, *47,* 1204–1210.

Zivkovic, P., Ilic, G., Tomic, M., Vukic, M., Stevanovic, Z., Stevanovic, Z., Ogrizovic, M., (2010). Air pollution estimation on the city of Niš territory. *Power Plants 2010, Vrnjačka Banja – Serbia*.

Washburn, S., Seet, S., Mannering, F., (2001). Statistical modeling of vehicle emissions from inspection/maintenance testing data: an exploratory analysis. *Transportation Research Part D*, 8 (2001), 21-36

Biographies

Aleksandra Boricic has been working as professor at the College of Applied Technical Sciences in Nis. She teaches in mechanical engineering and environment. Her Ph.D. is in environmental science. She has participated in more than 10 international/regional projects in monitoring key environmental parameters. She is a member of the HERE team (team for reforms of Serbian higher education system).

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